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Dynamic Anode Initialization to Mitigate Luminance Drop

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ABSTRACT

In AMOLED displays, the OLED anode is frequently reset to ensure that black regions in the display have low light emission. However, anode resetting has the unwanted side effect of slowing low luminance pixel response. This disclosure describes techniques to maintain the darkness of black regions of AMOLED displays while ensuring rapid pixel response. An anode initialization voltage bias is defined as the voltage at the source terminal of the transistor that effects the resetting of the OLED anode. The anode initialization voltage bias is adapted, or, alternatively, made to electrically float, based on the display brightness level such that dark pixels can rapidly respond to light emission demands. The OLED anode maintains a voltage just below its light emitting threshold voltage such that it can rapidly respond to sudden spikes in light emission demands while also maintaining the darkness of black pixels.

KEYWORDS

- Organic light emitting diode (OLED)
- Active matrix OLED (AMOLED)
- Leakage current
- Contrast ratio
- Luminance drop
- Color separation
- Anode bias

BACKGROUND

In active matrix organic light emitting diode (AMOLED) displays, the circuit of individual pixels re-initializes (resets) the OLED anode every frame or more frequently. Frequently resetting the OLED anode ensures that black regions in the display have low light emission, which provides a high contrast ratio.

While anode resetting minimizes the light emitted by black regions of the display, it also impacts the low luminance response time of the pixel. A pixel configured for low luminance has a low emission current (I_{OLED}). Combined with a reset anode, which has low (or zero) voltage, the low I_{OLED} takes a relatively long time to charge the anode beyond its light emitting threshold voltage. Consequently, the pixel luminance response is delayed. Even if the time-averaged luminance meets the target luminance, most photons are emitted by OLED at the later part of the frame.

When the image is static, the boundaries or edges of content (e.g., icons) displayed against a black (or dark) background are well defined. When the display is transitioning, e.g., in response to user action such as scrolling, the pixel intensity is required to change rapidly with time. However, slow pixel response results in content (e.g., icons) being displayed with low luminance such that the edges are blurred, when viewed against a black background. The low luminance effect is particularly apparent when the display has delayed responses such as low first frame luminance rate. The temporary lower-than-target luminance that lasts for a couple of frames combined with anode resetting results in low luminance and color separation.

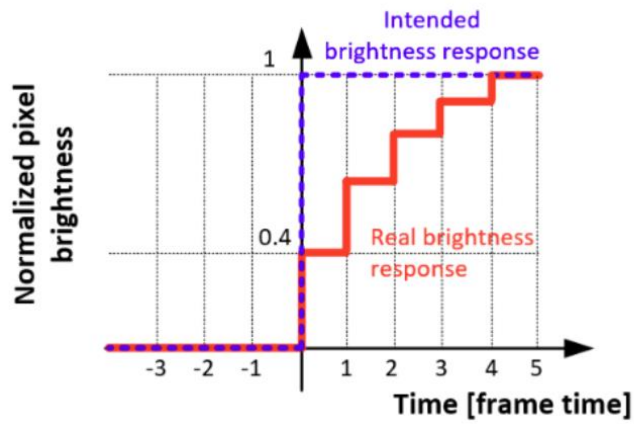
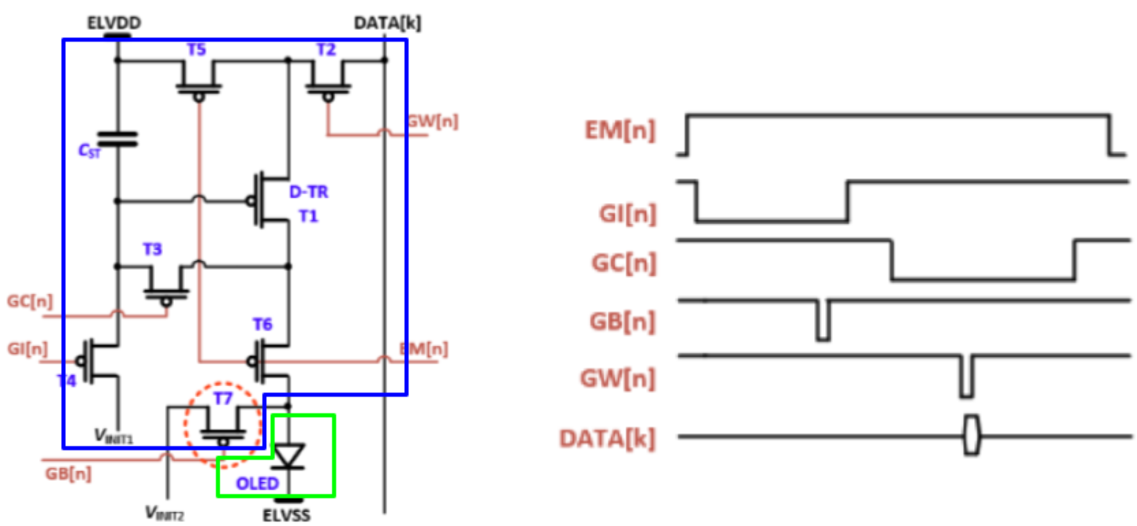


Fig. 1: Intended brightness response versus actual brightness response

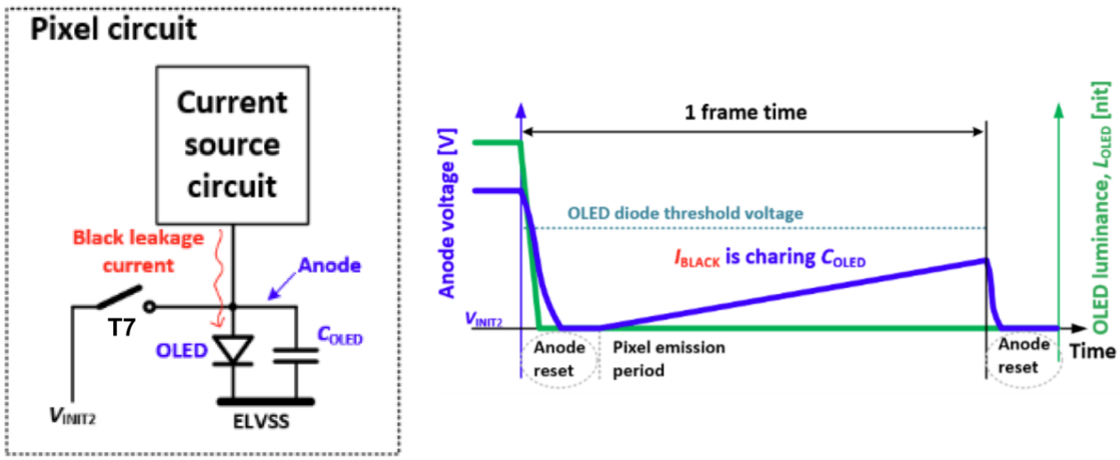
The slow pixel response in low luminance configuration is illustrated in Fig. 1, where the gap between the intended brightness response and the actual brightness response can be as large as four frames. Additionally, high OLED emission efficiency, which reduces power consumption, has an unwanted side effect where even a small leakage current from the pixel circuit generates noticeable stray light emission in the display.



(a) **(b)**

Fig. 2: (a) An OLED (within green polygon) with its control circuitry (within blue polygon); (b) The control signals of the OLED

Fig. 2(a) illustrates an OLED (within green polygon) of an AMOLED display and its control circuitry (within blue polygon). Fig. 2(b) illustrates the control signals of the control circuit.



(a) **(b)**

Fig. 3: (a) Schematic of an OLED and its control circuit; (b) Resetting the anode brings its voltage to zero, thereby reducing stray light emission from a dark pixel

Fig. 3(a) illustrates a schematic of an OLED and its control circuit, e.g., Fig. 3(a) is a simplified version of Fig. 2(a). Even when dark, the OLED receives from its control circuit a leakage current (I_{BLACK}), which charges the capacitance C_{OLED} across the OLED. Periodically (e.g., once per frame) closing the switch T7 results in the discharge of the capacitor C_{OLED}, bringing the anode voltage to zero Volts, e.g., resetting the anode of the OLED. This is illustrated in Fig. 3(b), where the anode voltage (blue curve) is brought to zero at the beginning of each frame, even as it rises due to the accumulation of charge from the leakage current I_{BLACK}. Doing so, the anode voltage remains below the light emitting threshold voltage of the OLED, such that the OLED remains dark (green curve of Fig. 3b). As explained before, although resetting the anode maintains the darkness of black pixels, it also slows the pixel response in low luminance configurations.

DESCRIPTION

This disclosure describes techniques to maintain the darkness of black regions of an AMOLED display while ensuring a rapid pixel response. An anode initialization voltage bias V_{INIT2} is defined as the voltage at the source terminal of the transistor that effects the resetting of the OLED anode. The anode initialization voltage bias V_{INIT2} is adapted based on the display brightness level such that dark pixels can rapidly respond to light emission demands. Alternatively, the anode initialization voltage bias V_{INIT2} is made to float depending on the display brightness level such that dark pixels can rapidly respond to light emission demands.

The techniques, described in greater detail below, leverage the observation that luminance drop and color separation are most noticeable when the display is under low brightness settings, and, under low brightness settings, the emission current I_{OLED} is small compared to the capacitance across the OLED.

Dynamic anode initialization to mitigate luminance drop by adapting the anode initialization voltage bias

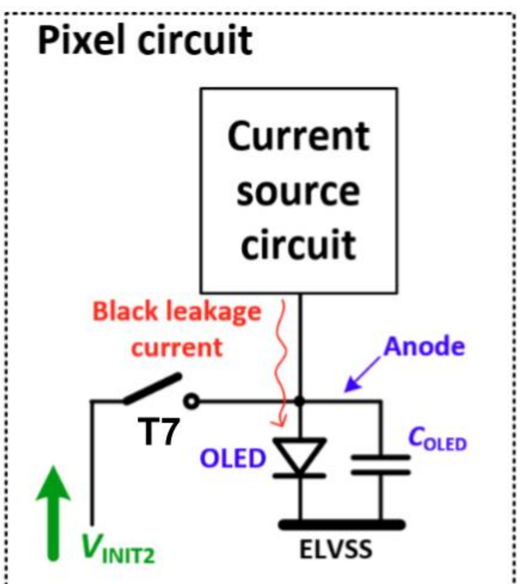


Fig. 4: Dynamic anode initialization to mitigate luminance drop by adapting the anode initialization voltage bias

Fig. 4 illustrates dynamic anode initialization (resetting) to mitigate luminance drop by adapting the anode initialization voltage bias V_{INIT2} at the source terminal transistor T7 that effects the resetting of the OLED anode. The anode initialization voltage bias V_{INIT2} is configured to inversely vary with the display brightness level. For example, when the display brightness is low, V_{INIT2} is made relatively high, and vice versa. By thus adapting V_{INIT2} to the display brightness level, the OLED capacitor (C_{OLED}) stays at a voltage level closer to, but still below, the light emitting threshold of the OLED. The just-below-threshold voltage of C_{OLED} enables the OLED to rapidly ramp up its light emission when light emission demand suddenly spikes up. V_{INIT2} can be precisely controlled to prevent it from going higher than the OLED threshold voltage. To further lower the risk of black luminance, the V_{INIT2} voltage bias electrode can be made to electrically float by increasing the impedance of its source.

Dynamic anode initialization to mitigate luminance drop by electrically floating the anode initialization voltage bias

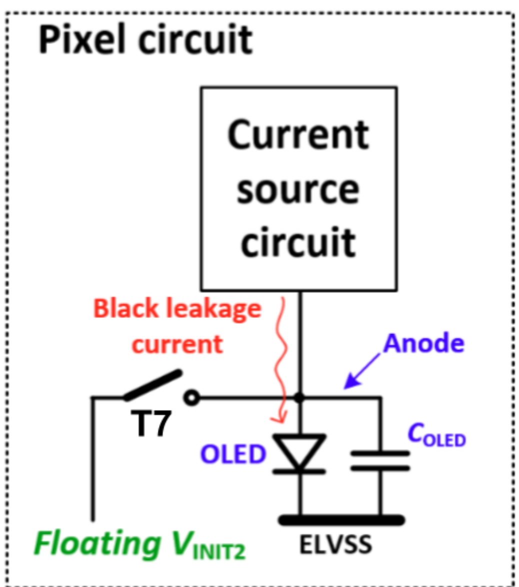


Fig. 5: Dynamic anode initialization to mitigate luminance drop by electrically floating the anode initialization voltage bias

Fig. 5 illustrates dynamic anode initialization (resetting) to mitigate luminance drop by electrically floating the anode initialization voltage bias V_{INIT2} at the source terminal of the transistor T7 that effects the resetting of the OLED anode. Specifically, the anode initialization voltage bias V_{INIT2} floats at a level dependent on the display brightness level. For example, if the display brightness is set to be lower than a certain threshold brightness, V_{INIT2} can be made to float. Anode resetting is obviated.

For both techniques, the black leakage current I_{BLACK} generally becomes lower at low brightness settings, making the risk of black luminance more manageable. The described techniques can be adopted for any device that includes an AMOLED display, e.g., a smartwatch, smartphone, etc.

CONCLUSION

This disclosure describes techniques to maintain the darkness of black regions of AMOLED displays while ensuring rapid pixel response. An anode initialization voltage bias is defined as the voltage at the source terminal of the transistor that effects the resetting of the OLED anode. The anode initialization voltage bias is adapted, or, alternatively, made to electrically float, based on the display brightness level such that dark pixels can rapidly respond to light emission demands. The OLED anode maintains a voltage just below its light emitting threshold voltage such that it can rapidly respond to sudden spikes in light emission demands while also maintaining the darkness of black pixels.

REFERENCES

1. Fan, Ching-Lin, Yi-Chiung Chen, Chuang-Cheng Yang, Yung-Kun Tsai, and Bohr-Ran Huang. "Novel LTPS-TFT pixel circuit with OLED luminance compensation for 3D AMOLED displays." *Journal of Display Technology* 12, no. 5 (2016): 425-428.